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AUTHOR	Ives, Quay D.
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ABSTRACT

The research reported is intended to provide a body of information on technical-scientific shop and laboratory education in the field of technological education. The study seeks to address the dearth of organized information on the utilization of laboratories in the technical education context. Various programs involving use of laboratories are explored. (RE)

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LABORATORY CHARACTERISTICS IN TECHNICAL EDUCATION

by

Dr. Quay D. Ives
Professor and Chairman Engineering Service Dept.

California State Polytechnic University, Pomona
Pomona, California

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INTRODUCTION STATEMENT

The California State Polytechnic University, Pomona received an NSF Grant to assist in the development of an engineering technology program. This engineering technology program is to be implemented within an existing School of Engineering. We have attempted to use the funds made available in such a way that educational institutions, in addition to Cal Poly, Pomona might benefit from our investigations, conclusions and recommendations. We have designated several areas in which we feel an input is needed in order to meaningfully develop an engineering technology program. One of these areas is that of laboratory equipment and facilities.

Dr. Quay D. Ives, Chairman of our Engineering Service Department, was asked to assist in establishing a model for engineering technology laboratories. His charge was as follows:

"Quay D. Ives August 7, 1973

In order to insure proper direction of the Engineering Technology Department at Cal Poly, Pomona and simultaneously contribute needed information to the National Community of Universities and Engineering Schools (via NSF Grant reporting), it is proposed that additional thought be given to the objective, constraints and controlling parameters of a viable and meaningful laboratory for Engineering Technology programs. Therefore, the following assignment is proposed to accomplish these ends:

Develop a concise model, or models, for Engineering Technology laboratories based on the following considerations:

1. Identify clearly and concisely the objective of the Engineering Technology laboratory and means of verifying the validity of the objective.

2. Expectations of industry as to student capability at graduation.

3. Identify clearly the Engineering Technology laboratory experience as compared to current and/or traditional disciplines.

4. Viable options, if any, for gaining practical or laboratory experience other than the University laboratory.

5. Constraints on facilities and equipment selection.

6. Roll the instructor plays in the Engineering Technology laboratory."

Dr. Ives report titled, "Laboratory Characteristics in Technical Education" approaches lab requirements for technical use simultaneously from a philosophical point of view and a practical point of view. This report should be of value to those people involved with technical education, whether it be engineering or engineering technology.

A CRITICAL ANALYSIS AND DETERMINATION OF TECHNICAL SCIENTIFIC SHOPS AND LABORATORY PROGRAM CHARACTERISTICS IN TECHNOLOGICAL EDUCATION: EMPHASIS UPON MIDDLE RANGE OF THE MANPOWER SPECTRUM

By: Dr. Quay D. Ives

INTRODUCTION

The research reported in this section of the study is designed to provide a body of information on technical-scientific shop and laboratory education in the field of technological education with emphasis upon the middle range of the manpower spectrum. Shop and laboratory facilities are generally considered to be an indispensable part of all technological education, for at some point in time man must translate his feelings and thoughts about things into an action process. This basic translation process can generally function more economically in a synthesized setting for action, a laboratory, rather than in the real world where final proofs must be obtained.

Scientists have always recognized that new knowledge is a product of the laboratory rather than a product of academic search in the library. Experimentation and discovery are the essential hallmarks of technological education. Technological education is directly related to the defense and welfare of this nation. At present there appears to be no organized body of material on this subject: this study has been attempted in order to gain more knowledge on the utilization of these facilities as they now exist in our society. It is hoped that the material presented will not only serve to profile this important area

of educational endeavor, but more importantly, provide increased awareness. It is also hoped that this will result in further research in this field of endeavor.

The twentieth century has witnessed an unprecedented development within the field of technological education. Its growth and development run parallel to the expansion of knowledge and the many new advances in the technical skills. At the same time technological education has served to stimulate and accelerate the further development of technology. The resulting condition has led to the need for better ways of providing for the transmission of knowledge, understanding, judgment, and skill for the future worker at all levels and in all areas of endeavor. The problem was stated by HERBERT SCHENCK, JR. in the following manner:

> Lack of time is at the root of many problems in modern education, and nowhere is this truer than in engineering. Any project that leads to equal or better understanding of a topic with an attendant decrease in time spent will be a valuable and desirable contribution. (1)

To further support the fact that shops and laboratories are an indispensable part of all technological education, we will turn to a statement by W. H. ROADSTRUM in his text, Excellence in Engineering:

> It is important to keep in mind that reading and study alone cannot solve problems. Rather it is the combination of thoughtful study with remedial action--trying out the new ideas in daily work--that brings results. (2)
>
> One of the commonest ways of solving problems in engineering practice is by laboratory experiments.---Work in the laboratory is usually an important part of your early experience, and it will continue to be important to you in one way or another as your career develops.
>
> There are few indifferent engineers in the matter of laboratory work. Most engineers are either very fond of working with physical equipment or dislike it heartily. The first group would use the laboratory to solve just about every problem encountered. The second is convinced that analytical solutions are the only respectable part of engineering problem solving.

> Actually neither group is very near to the truth. Laboratory work, like any other engineering procedure, is a means to an end. It is only one specific tool to be used in solving engineering problems. Like any other tool, it has its best applications and is to be employed with discrimination. You will want to examine this tool, determine its characteristics, learn what its best uses and limitations are, and see what you can do to keep it sharp and effective. (3)

In order to accommodate the demand for increased specialization and, at the same time, cope with the greater breadth of subject matter, many engineering institutions have deleted shops and laboratories as a matter of expedience. SCHENCK states:

> The extensive laboratory work required of undergraduate students in engineering used to involve at lease a single weekly session in each of six semesters. During the past decade, laboratory time has shrunk to half this amount or less. At the same time, more and more students are undertaking graduate work at the master's level or higher, such work requiring in most cases considerable original research, the planning of experimental programs, data analysis, and the writing of some type of thesis and/or professional journal papers for publication. Clearly the two trends are counter-working. An undergraduate who has never used an oscilloscope or airflow meter is liable to make an appalling job of even the simplest thesis research and, indeed, many do.
>
> Recognizing this, engineering teachers have tried to replace the "cookbook" material in what few laboratory hours are left in their undergraduate curriculums by more or less original project work, thereby totally eliminating all use-instruction and lecture based experiments.
>
> This is a trend difficult to argue with in a fast expanding technology. The purpose of laboratory work in the modern day should be to teach people to experiment. The actual subject of the test is irrelevant, providing only that it is interesting, challenging, and not something that can be called from "fraternity files" of past years. (4)

It appears there are no extensive studies comparing the value of a theoretical program based upon a pseudoscientific approach of analysis and a similar program reinforced with the traditional shops and laboratories that previously gave technological education its specific character. This fact is rather surprising in light of the fact that

these engineering disciplines are heavily research oriented. Their programs purport to utilize the scientific method. They utilize the field of science as an area of applied science. Engineering education's purpose is largely to teach the student how to utilize the scientific procedure.

The laboratory is an essential part of the scientific procedure as the last step calls for testing the hypothesis in a field of action. ROSS G. HENNINGER noted the following:

> Survey visitation and discussion revealed that there is a general confusion about the question of the place of the "shop" facilities and instruction in a truly technical institute program. In engineering curriculums of bygone years, shop facilities and shop courses played prominent roles - foundry in mechanical engineering and motor rewinding in electrical engineering, for example. Current trends in engineering education, however, have essentially eliminated all such topics, as engineering develops to embrace the advanced and expanding realms of science. (5)

HERBERT A. ESTRIN in his text on Higher Education in Engineering Science, states that research and authorship certainly add to the prestige and recognition of an institution. He further states that there is no doubt about the fact that we need to turn out more theoretical engineers than we have in the past, as this has been a historic trend since the first college of engineering was founded. He then tersely writes the following:

> In our zeal to accomplish this desirable result, however, there is danger that we shall lose sight of the real difference between a theoretically trained engineer and a scientist. It would be most unfortunate, in my opinion, if the Colleges of Engineering suddenly were to devote their attention to graduating pseudo-scientists rather than engineers. (6)

Some have justified this trend upon the basis that the competencies of the engineer no longer call for expertise in the shop or laboratory because he is now a member of a team and these activities

are better handled by a technologist or a technician. Others state that the discontinuance of shops and laboratories is now accelerated by the fact that the new generation of engineers have developed little regard for work in these areas as their educational experience has been directed to the analytical aspects of engineering. Some claim that the accreditation process has been influenced unduly by those of greater educational attainment and thus engineering has been heavily skewed toward the science end of the technological spectrum. What has failed to emerge from the present scene is an in depth analysis of specific competencies unique to each of the various areas of technical endeavor and methods which best develop these competencies.

The complexities associated with this study were indicated in the Final Report of Engineering Technology Education Study made by the American Society for Engineering Education in January, 1972.

> No adequate data were found that would permit meaningful comparisons of laboratory equipment and facilities between various kinds of technology programs or between technology and engineering or physical sciences programs. Square feet of laboratory space, value of equipment, and other data usually submitted as a part of the evaluation for accreditation vary so widely from institution to institution -- even for similar programs -- as to be essentially useless for differentiation.
>
> A qualitative evaluation of the technology laboratories visited indicate in general they were oriented more towards production or testing than towards research or experimentation. Because of the perceived need to develop technical skills, there frequently were extensive production or shop laboratories and large drafting rooms. With commercially manufactured laboratory equipment becoming increasingly available, there appears to be a small trend toward more standard experimental or demonstration laboratories in technology programs. (7)

In any discussion which focuses upon education we all instantly become experts. The reason for this phenomena is that each of us has acquired some knowledge of education by virtue of having experienced the

educational process in a variety of different situations. Few of us have built an understanding based upon the knowledge we have gained. In general, we do not search out the historical roots, the educational philosophy, the psychological methods, or the sociological processes that support our present forms of education which provide the basis for trends taking place. Most of us see only small isolated pieces of a rather large complex picture.

Some educators have experienced teaching on a broad basis in that they have been involved with the educational process on a number of different grade levels. Others have become highly specialized within a particular area of interest. It is only natural that both of these specialists see the many different interfaces to their discipline. The problem arises when each educator desires to bring these many and varied interfaces within his particular discipline. What is sorely needed is a plan of action to separate the various disciplines based upon the essential function they perform.

Obviously the elements of the problem are extensive, the parameters are diverse and varied, the constraints are limitless, and the assumptions are valid only when seen in reference to a specific setting. The reader must not expect to find specific detailed information, but rather a delineation of ideas and concepts relating to the problem. The value of the research appears to be directly proportional to the breadth of view or scope of the undertaking for there exists a large and comprehensive body of relationships.

To make a critical appraisal of the problem calls for a determined list of questions to which answers are sought. The general analytical questions asked are as follows:

1. What early developments gave shape to modern day technological shops and laboratories?

2. What is the spectrum of shop and laboratory utilization in technological education?

3. What are the interfaces between these different forms of technological education?

4. What commonalities exist between these different forms of technological education?

5. What does the current status of Engineering Technology appear to be?

6. What significant trends are under way?

7. What needs does Engineering Technology appear to meet?

8. What major constraints or limitations appear to focus upon shop and laboratory program requirements in Engineering Technology?

9. Educationally speaking, what are some of the possible courses of action open to Engineering Technology?

10. What is the educational process that shapes the development of shops and laboratories in technological education?

11. What constitutes a meaningful shop or laboratory experience in Technological Education?

12. What are some of the various roles the student plays in laboratory work?

13. What roles are typical for the instructor of technological laboratories?

14. How does an Engineering Technology laboratory differ from other forms of technological laboratories?

15. What other forms of experience are substituted for laboratory instruction?

16. What options exist for maximum laboratory utilization?

17. How may laboratory experiences be compared and evaluated?

18. What controls appear to be necessary to guide the development of Engineering Technology laboratories?

19. What effect does employment opportunity have with respect to shop and laboratory experience in Engineering Technology?

20. How can the analysis and determination made in this study serve Engineering Technology?

All of these questions are interrelated and offer an important point of perspective in utilizing educational shops and laboratories in the field of Technological education. In general they are supportive to providing a measure of reality within the school system. Whether they are in a school or industrial setting they definitely fall within the context of scientific problem solving.

THREADS OF DEVELOPMENT

Socrates was once asked what constitutes the ideal educational situation. He replied that the best situation was to educate youth by providing opportunities for experience within the society in which the student would live. Today this is not possible; consequently, society has turned toward similar educational situations within formal education. This process can be costly and it never can completely achieve the exact reference of real industrial experience.

In the prehistoric beginnings of the race, man learned by experimentation and its concomitant experience. Learning was then a resultant product of experience. Man learned that by repeating an act in or under a specific set order of conditions that he could influence the outcome of events. Technology, the act of achieving a practical purpose, is as old as man himself. What has changed in the last period of time is that man has gained so much knowledge about the laws and principles of the Universe that he can now shape events through the benefits of art and science, without following his earlier established routine of moving from an event to an artful way of accomplishing

something to eventually discover the fundamental principles of science.

How strange it is that modern educational processes can be viewed in opposition to the normal processes of learning. The normal process is to experience, and through this experience we learn. Today our educational processes are designed to teach a specific item of subject matter and then this learning is enhanced with accompanying and specifically designed experiences. It is important to note that shop and laboratory work is dynamic in that there is a constant interchange at work between both basic approaches to learning.

ROBERT PERRUCCI and JOEL E. GERSTL in their book, The Engineers and the Social System, describe the slow formation of a profession of engineering.

> The economics of ancient civilizations did not require the organized development and application of technology for which an engineering profession was necessary. The prevailing technology was a product of trial and error, intuition, artistry, and the gross synthesis of experience unsupported by science. (8)

There are many threads that have brought the world to the present revolutionary advance in science and technology. The craftsman has persisted through all ages up to the present; however, his significance came to a focal point during the middle ages. In time, apprenticeship systems developed as a natural outgrowth of the master-craftsmen attempting to extend their operations through apprentices. During the sixteenth and seventeenth centuries the scientific effort of the earlier Societies of Science created a new basis for technology. During the eighteenth and nineteenth centuries the "Factory System" created a need for workers in a variety of different fields. At this time there was a great deal of overlapping in the various fields of scientific endeavor.

The first true engineering school was established at the United States Military Academy at West Point in 1802. This was followed by other institutions interested in Science and Engineering. Some of these institutions are as follows: Rensslaer Polytechnic in 1824, Franklin Institute in 1824, M.I.T. in 1865, Hampton Normal in 1868, Tuskeger Institute in 1881, Carnegie Institute in 1905, Cal Tech in 1905, and Cal Poly in 1903.

Concurrent with the development of early engineering institutions was the development of the Mechanics Institutes during the years 1824-1855. This was a natural consequence of the development of steam power in the 1700's. Later, as electrical power came into its own in the early 1900's, whole new industries were developed. The Manual Training Movement began in 1825. The Civil War brought about a renewal of interest in technical education. In 1862 the Morrill Act was passed by Congress. This bill established the system of land grant colleges in the United States. These schools were designed to advance the education of the farmer and the mechanic. Later they became the basis for our present system of engineering schools. During the years 1868 to 1912 the Trade School Movement flourished.

In 1875 the European Exhibit at the Philadelphia Centennial Exposition injected new vigor in a variety of experimental shop programs during the 1880's. Manual Training Programs were established but later gave way to the Vocational Education Movement which got under way in 1905. A program of industrial arts was developed at Berkeley and Los Angeles in the Junior High Schools. By 1929 Industrial Arts was an established college program at San Jose, California. All of these programs and movements flourished and assisted America in providing

technical workers for a variety of employment levels. An overview of this historic background appears to support a trend for ever greater specialization.

The Industrial Arts Programs were nationally accepted by the 1930's. Fresno offered a B.S. in Industrial Technology as early as 1948. By 1957 the Junior Colleges embarked upon a program of Technical Education and Applied Science. In 1963 the Vocational Education Act reaffirmed a strong position for various programs of technical education. In the last five or six years a few new programs of engineering technology were developed in our Engineering Institutions. All of these various programs have some things in common, the most significant being their use of the scientific method of controlled experimentation and the utilization of the current industrial scene as a base for the educational process.

Industry and the Federal Government utilize the concept known as the division of labor. This program is currently visible in the D.O.T., Dictionary of Occupational Titles, and each specific occupation is delineated in terms of its requirements. This document serves as a guide, but Industry continues to establish a wide range of positions in keeping with its specific needs. The results of these many programs of education, methods of classification, and actual practices add up to a need for a composite approach or system. It is the writer's belief that such a system can be developed if programs, descriptions, and applications can be resolved upon the essential characteristics in each classification. While this study can account for only a small part of a total study that needs to be done, it may provide for the development of new interest and a point of departure for additional

studies. The usability of this study will depend upon how it fits the developments of the past and, again, upon how it fits reality and the foreseeable future. It is hoped that this study will elicit a similar or empathic point of view for those who read this document.

When the word Technology is used in this paper it is meant to include all phases of basic and applied science. It is best defined as a technical method of achieving a practical purpose by the use of Art and Science. It is important to point out that Art, Technology, and Science are constructs or products which man uses to cope with the complexities of life. They do not exist in reality. On a similar basis the words like operator, technician, technologist, engineer, and scientist are also constructs. While we may have a general feeling for the exactitude of these words they generally are not specific because the frame of reference held by all others is diverse and varied.

The words shop and laboratory are also symbols or constructs covering a wide and diverse array of facilities. The writer's definition of a shop is a period of time or a place equipped with tools and industrial machines designed for the purpose of processing materials. A school shop has the same connotation as shop except that it exists for the basic purpose of helping students understand the ramifications of Art, Technology, and Science as utilized by our technological society. The word laboratory is defined by the writer as a period of time or a place equipped to provide opportunities for experimentation, observation, testing, analysis, or practice within a specific field of study. Again, the school laboratory has the same connotation as laboratory except that it exists for the basic purpose of helping the student understand the ramifications of Art, Technology, and Science as utilized

by our technological society. While this study utilizes both the terms shop and laboratory, there is very little difference. The same physical facility might be classified as a shop or as a laboratory based upon its specific function.

There is also further recognition that these definitions are dealing with constructs that can more properly be classified as an amplification of normal thought and action processes. Art is that aspect of thought and action which deals with the human equation. In short, it is relating the "me in here" (desires of man) to the "it out there" (reality or nature). Science relates to the "it out there." Reality for man is both nature and self and the resulting relationship. Once these relationships have been grasped it is possible to understand the significance of Technology. Technology can be identified as the process of utilization by which we utilize the "it out there" for the "me in here." Technology is the method or procedure whereby man achieves a practical purpose for man. It is a sequential ordering of tasks.

This study then consists of a myriad of relationships that are not simple, single, or isolated. To summarize or to subsume the facts into a construct requires that essential characteristics of the data be used. Subsumation appears to be most discernible when organized around the concepts of structure, function, and method. Structure implies that concern will be made for the field of operations; function implies point of focus or purpose; and method refers to accepted practices.

We must examine the structure of this problem in reference to technical-scientific education within our industrial society. The function to be performed is to make a critical appraisal of facilities utilized in technological education. This means that the basic action

will not only be based upon the environmental structure, but also upon what the individual perceives things to be and upon the task to be done. The ultimate task is conceived to be the development of a construct that will provide for a systems approach so that effort may be optimally organized. Method is essentially analysis tempered with thoughts, feelings, and action about space, time, self, and the forces at work in the universe (truth). It is involved with Process, Procedure, and Design.

It is hoped that the reader will be generous enough to evaluate this study based upon the author's use of generalization conceived in terms of the unique characteristics of each classification. In some cases the use of terminology may not suit the reader, and he may find that the writer has missed the point by virtue of the reader's own specialized frame of reference. The author has tried to objectively view the problem from a total point of view without bias.

TYPES OF PROGRAMS

American public education embraces a number of different technical-science programs. This is further complicated by the particular structure of grades within the community. Some systems include grades seven and eight as a part of the elementary system. In recent years many schools have accepted grades seven, eight, and nine as the basis of a junior high program. Grades nine through twelve or ten through twelve are seen as the high school grades. Upon completion of high school the student has a variety of programs available for his further development.

Grades one through six are generally conceived of as an integrated program of instruction. Industrial Art may be offered as an

experience with tools or as an experience building objects for a learning unit. Grades seven and eight or seven, eight, and nine introduce specialized courses of instruction aimed at exploration of occupations. Exploratory Industrial Arts usually acquaints the student with a laboratory of industry concept. The student may rotate through a series of unitized laboratories centered upon major materials or concepts, i.e., woods, metals, electricity, photography, crafts and graphics. The objective being to provide real life experiences with regard to materials, processes, operations, industrial organization and occupations. The Industrial Arts Program in high school may continue through all four years. At this level the educational experience is pre-vocational. The program continues in the junior college or four year institution as Teacher Preparation or if Industrial Technology is taken it aims at employment.

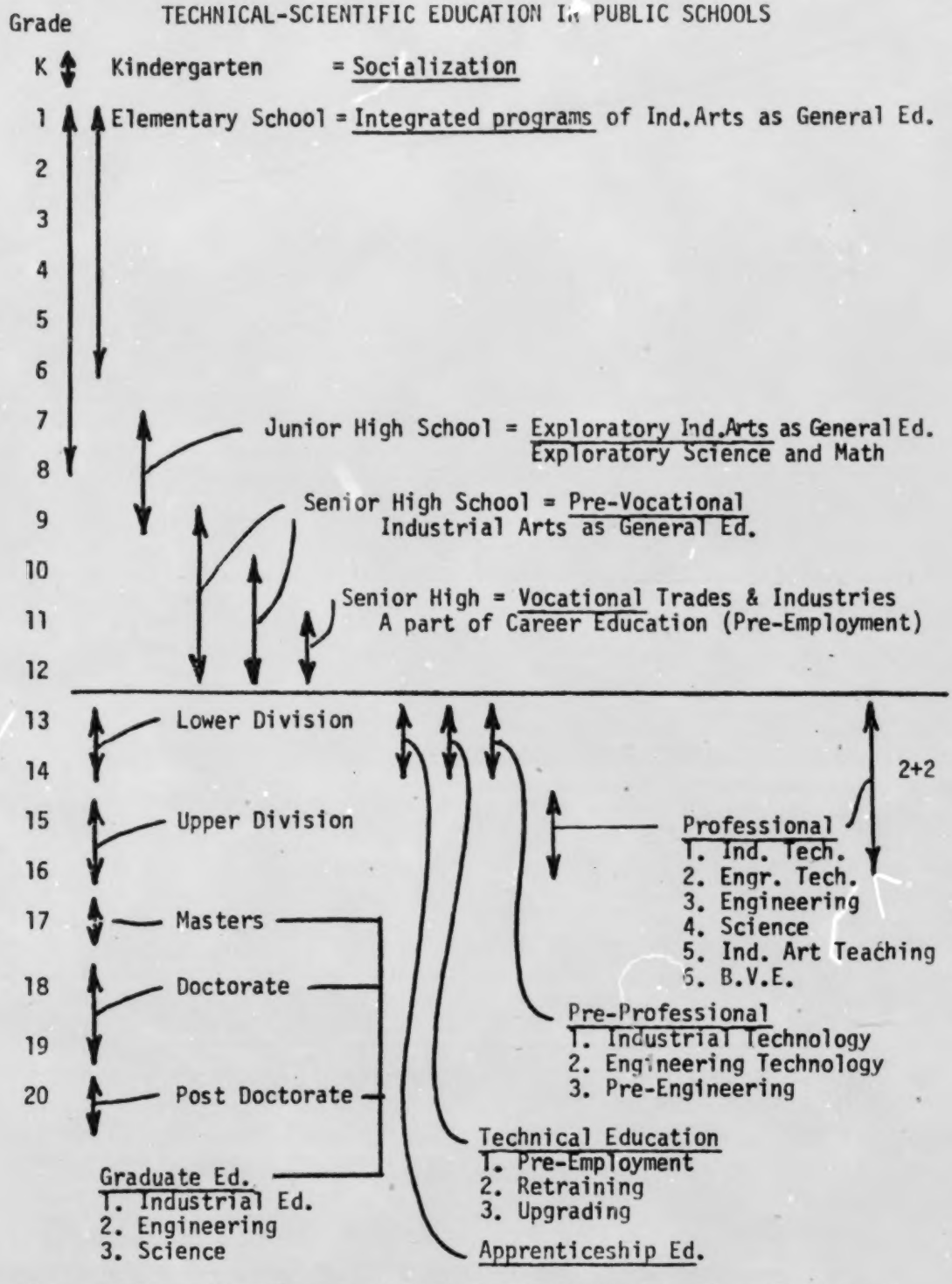
Vocational Education usually starts in grades ten to twelve. Its aim is gainful employment. The trades and industry program is pre-employment training in trades or technical occupations. The vocational program in the junior college aims at pre-employment, upgrading, and retraining. Students receiving training beyond the junior college level traditionally take a program of Industrial Education, Industrial Education in this sense, being a combination of Industrial Arts and Vocational Education. Vocational Education in the junior college may also take the form of an apprenticeship. In recent years junior colleges have offered technical education as a form of vocational education leading to employment as a technician.

Engineering Technology may begin with technical education in the junior college, but must be completed with two years of additional work

in a four year institution for qualification as a technologist. Some junior colleges set up special programs referred to as pre-engineering. These programs aim at the first two years of engineering education but they may also contain some technical education courses such as graphics and machine shop. This education may be described as pre-professional.

Please note that the following diagram indicates basic types of technical education within the public school system. Options become greater upon completion of four years of high school. Students can however participate in some post-high school vocational programs without having received a high school diploma.

The following construct will provide an overview of the functions these different programs serve at the various grade levels.



Note: Programs in Science and Math are available in all grades beyond twelve as specialized areas of endeavor.

CONSTRUCTS DEVELOPED

At present there are five major types of technical-scientific classifications within the spectrum of employment. They are as follows:

Technical Scientific Employment

1. Operator
2. Technician
3. Technologist
4. Engineer
5. Scientist

If these five types can be clearly identified there must be at least five types of shops or laboratories to serve the basic functions of each group of employment. These specific types of shops or laboratories should be optimized in terms of the educational function to be accomplished. The type of shop or laboratory to be identified with these groups of technical-scientific activities appear to be as follows:

Technical Scientific Employment	Type of Shop or Laboratory
1. Operator	1. Vocational
2. Technician	2. Technical (Voc. - Tech.)
3. Technologist	3. Industrial
4. Engineer	4. Experimental
5. Scientist	5. Science

Obviously these types of shops and laboratories possess many similar characteristics in that they are interrelated and in varying degrees utilize materials, tools, equipment, processes, operations, tasks and techniques common to the industrial establishment. The scientist on the one end of the spectrum uses all these things for the singular purpose of constructing specialized scientific apparatus. The operator on the other end of the spectrum is concerned with the same things, but from the concept of skill development in operation of equipment to produce parts. Between the two ends of skills and theoretical

concerns we find a variety of functions that serve basic educational purposes in each classification. These may be as follows:

Types of Shop or Laboratories	Functions of Shop or Lab
1. Vocational	1. Education for production of parts and subsequent assembly.
2. Technical	2. Education for specialized technical expertise concerning production operations.
3. Industrial	3. Education in manufacturing research, process, and systems of human interface to machines.
4. Experimental	4. Education in applications of science to translate principles into usable forms for man.
5. Science	5. Education in exploration of phenomena to discover scientific principles

The functions of shop and laboratory use span the functional outcomes of education, i.e., knowledge, understanding, judgment and skill. The method by which these various types of shops and laboratories achieve their ends relates to the creative, technical and logical ways man resolves problems. In the case of shops and laboratories it also relates to the type of equipment and the basic concepts of organization.

The most useful methods for education have stemmed from the field of psychology for they are based upon the study of the mind under various conditions. Educational Psychology suggests the following considerations:

1. Perceived Purpose -- establishes learning set through relationships (past and present) to suggest a setting of application and experimentation in concrete undertakings.

2. Individualized Differentiation -- based on individualization (Maturity Level) as learning is an intimate affair involving the whole personality as a continuous process.

3. Graduated Sequence -- based upon psychological concepts

   a. Known to unknown
   b. Simple to complex
   c. Concrete to abstract

4. Active Response -- based on use of material under like circumstances (actual life concerns) content to have real truth elements relating to interest and problems.

5. Appropriate Practice -- based on concept of building (firsthand experience). Reality consists of dealing with symbols, abstractions, as well as environment.

6. Knowledge of Results -- based on principle that learning must be used (Law of use and disuse). Involves skill, habits, attitudes, knowledge and other acquired conduct. (9)

Steps one, two and three are basic to all forms of education. Steps four, five and six emphasize the need for shop and laboratory work in the educational process.

To further develop material for a construct, analysis will be drawn with reference to Essential Methods of Problem Solving, Types of Equipment, and Basic Organizational Concepts.

Types of Shops and Laboratories	Essential Methods of Problem Solving
1. Operator	Normal Basic Actions
2. Technician	Orderly Procedures
3. Technologist	Observations and Tests
4. Engineer	Theoretical Computations
5. Scientist	Conceptual Delineation

Types of Shops and Laboratories	Types of Equipment	Examples
1. Operator	Multiple units of a variety of simple industrial equipment.	AAA BBB CCC
2. Technician	Groups of types of Industrial equipment by function	A_1 A_2 A_3 A_4 A_5 A_6
3. Technologist	Instrumented manufacturing testing devices complete industrial processes	A → B → C
4. Engineer	Only enough instrumented equipment to test for concept of utilization	+ - Values
5. Scientist	Construction and manipulation of special scientific apparatus	Item of Concern

Types of Shops and Laboratories	Basic Organizational Concepts
1. Operator	Simplified Operations
2. Technician	Unitized Expertise
3. Technologist	Systematized Processes
4. Engineer	Instrumented Tests
5. Scientist	Devised Experiments

From the foregoing summarizations it is now possible to subsume the above facts into a construct. In totality the facts take on greater importance. As in Gestalt psychology, the sum is equal to more than the sum of its parts. A few additional words have been added to the following construct to stress the material presented.

CONSTRUCT OF TECHNICAL-SCIENTIFIC PROGRAM OF INSTRUCTION
AND RELATIONSHIPS TO INDUSTRIAL CONCERNS

AREA OF TECHNICAL-SCIENTIFIC EMPLOYMENT	TYPE OF SHOP OR LAB	FUNCTION OF SHOP OR LAB	BASIC ORGANIZATIONAL CONCEPT	ESSENTIAL METHODS PROB. SOLV.	TYPES OF EQUIPMENT	EXAMPLE
1. OPERATOR (Production)	VOC LAB	Education for Production of Parts and Subsequent Assembly	Simplified Operations	Normal Basic Actions	Multiple units of a Variety of Simple Industrial Equipment	A A A B B B C C C
2. TECHNICIAN (Operations)	TECH LAB	Education for Specialized Technical Expertise Concerning Production Operations	Unitized Expertise	Orderly Procedures	Groups of types of Industrial Equipment by Function	A_1 A_2 A_3 A_4 A_5 A_6
3. TECHNOLOGIST (Development)	IND LAB	Education in Manufacturing Research, Processes and Systems of Human Interface to Machines	Systematized Process	Observation and Tests	Instrumented Mfg. Test Devices & Complete Industrial Processes	A→B→C
4. ENGINEER (Design)	EXP LAB	Education in Applications of Science to Translate Principles into Usable Forms for Man	Instrumented Tests	Theoretical Computations	Only Enough Itemized Equipment to Test for Concept of Utilization	+ - Values
5. SCIENTIST (Research)	SCI LAB	Education in Exploration of Phenomena to Discover Scientific Principles	Devised Experiments	Conceptual Delineation	Construction and Manipulation of Special Scientific Apparatus	Item of Concern

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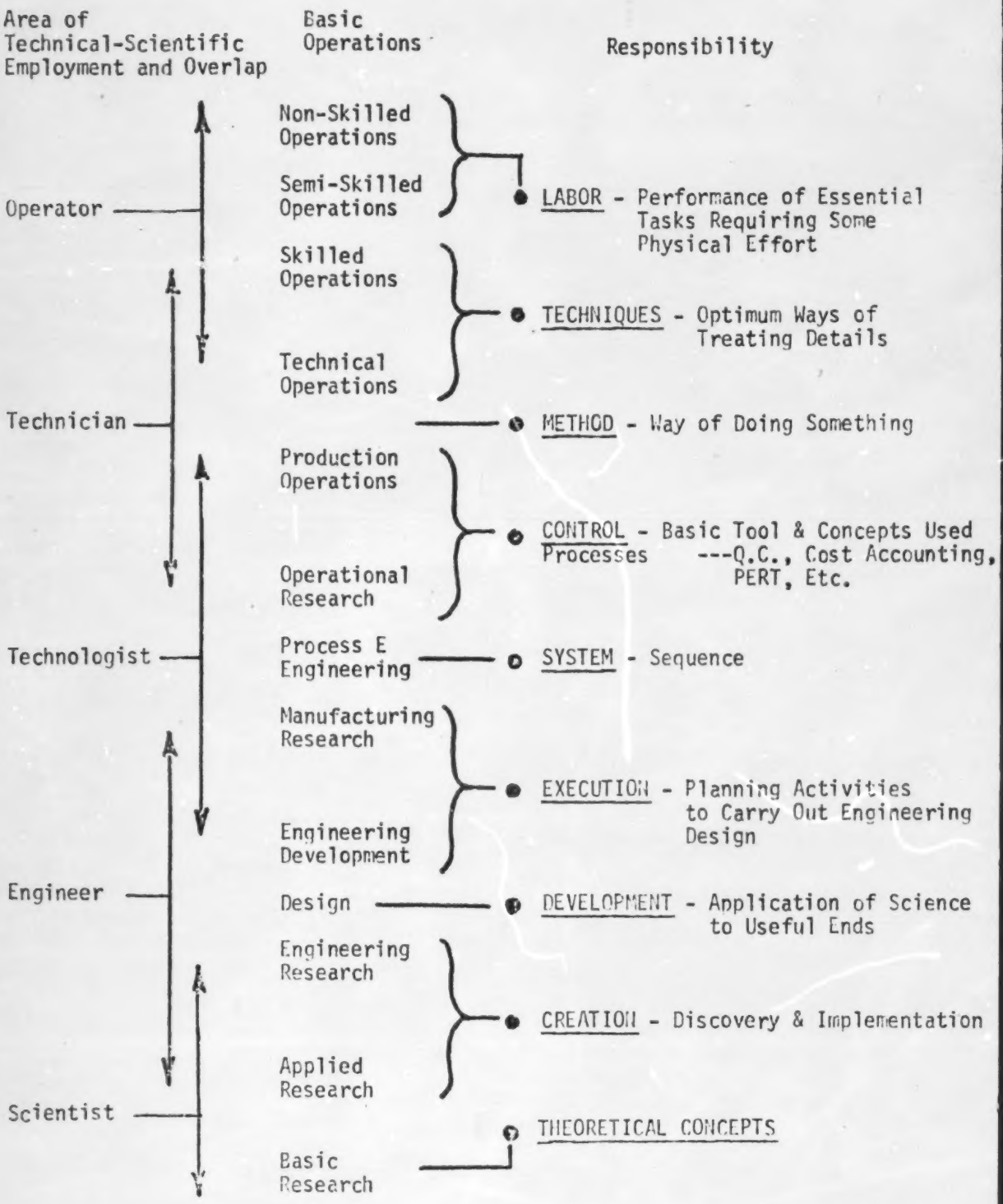
Now that we have identified the various types of technical-scientific endeavor with their specific characteristics, it is important to note that in reality they do not exist with clearly defined limits. The following construct shows the present overlapping between technical-scientific areas of employment and the basic operations and responsibilities involved.

CONSTRUCT OF TECHNICAL-SCIENTIFIC EMPLOYMENT AND OVERLAPPING OPERATIONS AND JOINT RESPONSIBILITIES



Note: The above items are involved in each area of employment but chief effort shows joint responsibility.

The Scientific Method can be broken into the following seven-step system:

1. Identify the problem
2. Define the problem
3. Formulate the hypothesis
4. Collect and Organize data
5. Verify the hypothesis
6. Formulate conclusions
7. Test hypothesis in the field

While the above steps are used in any one of the areas of technical-scientific employment, it is interesting to speculate upon these steps becoming specialized functions within industry. The following construct indicates that industrial society has not seen the end of specialization and the adjustments of accompanying functions. One could speculate that there will be a further refinement in specialization. Please note details on next construct.

POSSIBLE FUTURE SPECIALIZATION AND ADJUSTMENT OF ACCOMPANYING FUNCTIONS

Steps - Scientific Process	Basic Functions	Possible Areas of Employment	
1. IDENTIFY THE PROBLEM (Speculative Use of Scientific Facts)	BASIC AND APPLIED RESEARCH (Visualize Limits)	SCIENTIST	Science Lab
2. DEFINE THE PROBLEM (Product Design)	ENGINEERING RESEARCH AND DEVELOPMENT (Specific Conditions)	ENGINEER	Engr. or Experimental Lab
3. FORMULATE HYPOTHESIS (Process Refinements) (Economics)	MANUFACTURING RESEARCH (Work Conditions)	MANUFACTURING ENGINEER	Mfg. Engrg. Research - Systems Lab
4. COLLECT & ORGANIZE DATA (Plan of Work) (Communications)	OPERATIONS RESEARCH (Assignment of Manpower)	OPERATIONAL TECHNOLOGIST	Operations or Methods Lab
5. VERIFY HYPOTHESIS (Sequence of Tasks)	PRODUCTION OPERATIONS (Duties & Responsibilities)	PRODUCTION TECHNICIAN	Production Lab
6. FORMULATE CONCLUSIONS (Critical Path)	TECHNICAL OPERATIONS (Production Relationships)	TECHNICIAN	Technical Lab
7. TEST HYPOTHESIS IN THE FIELD (Optimum Performance)	SKILLED OPERATIONS (Repetitive Acts)	OPERATOR	Vocational Lab

Before leaving the topic of types of shops and laboratories the writer would like to point out that several other types exist in the industrial scene. Many companies have engineering shops and laboratories aimed at Engineering Development. Some have prototype or model shops which prevent production lines from being interrupted. In addition, some companies have manufacturing engineering shops and laboratories designed for the testing and improvement of manufacturing processes. If the manufacturing plant processes its products on a functional basis in lieu of a production line there may be unit shops such as: machining, stamping, casting, foundry, forging, welding, plastics, finishing, assembly, packaging, inspection and maintenance. Laboratories in industry are used to solve problems and to produce hardware. Educational shops serve the additional purpose of education. If educational courses and their activities aim at creating a research orientation then shops and laboratories must be used to resolve research.

HYPOTHETICAL QUESTIONS ANSWERED

Q 1. What early developments gave shape to modern day technological shops and laboratories?

A 1. Modern day technological shops and laboratories are largely based upon the successes of men. Progress is largely based upon empiricism and utilizes matter and power to create for man the possibilities of civilization. JOHN R. WHINNEY directs our attention to an inescapable fact in his book, The World of Engineering: "The story of civilization is, in a sense, the story of engineering -- that long arduous struggle to make the forces of nature work for man's good." (10)

Man's ability to meet change by creative and innovative products and services shapes the field of action and research in the shops and laboratories of our schools and industries.

DANIEL V. DeSIMONE in his treatise, Education for Innovation, states, "Moreover, existing knowledge about the world of technological change is not only rudimentary, it is disorderly." (11)

Disorder for man lies in his inability to place total cause and effect in focus at a point in time. The totality of things evades the process of discernment and progress is based upon finite pieces of truth couched in specific contexts. In reality man lives in an orderly universe. It becomes orderly as he develops theories which coincide with the development of applied science.

The events of the past are too prodigious to repeat in this paper. All that can be said is that today's shops and laboratories have been shaped by the historic past and as dynamic tools of man they

will undergo many changes in the future, many of which are beyond our wildest imagination.

Q 2. What is the spectrum of shop and laboratory utilization in technological education?

A 2. A great deal of confusion exists in the minds of people as to what constitutes the spectrum of technological education. On one hand the spectrum is as large as the industrial scene, for industry is the umbrella for all construction and production of products and services.

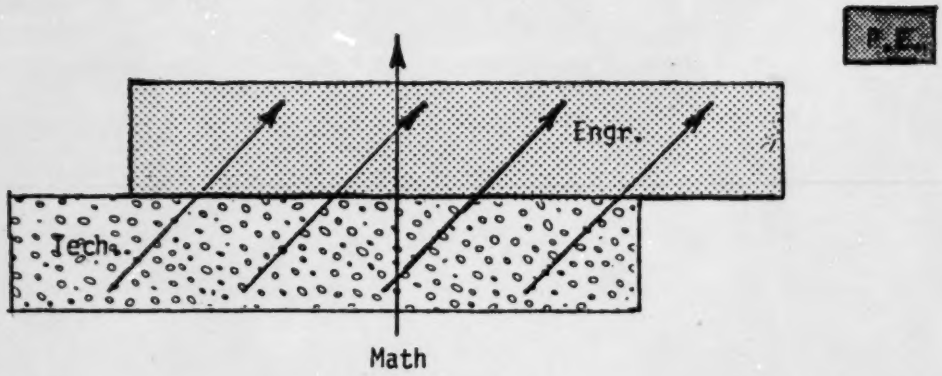
Life is education and education is life. The entire experience of living is undergirded by observation and experimentation in our environment. In specific areas we establish types of facilities as delineated in the constructs on pages 22 and 26 in this paper.

It is easy to jump to the conclusion that all learning should contain some observation and experimentation in the learning process. A chief disadvantage of learning in shops and laboratories is that the student does not have time to experience everything. Participation in this area of learning has its limitations. However, those things he does experience serve as reinforcement for mastery of trial and error and cause and effect relationships. Reality is a stern teacher.

Q 3. What are the interfaces between these different forms of technological education?

A 3. For all practical purposes there are no interfaces. Extensive amounts of effort have been utilized in trying to delineate the hypothetical interfaces. This is most apparent in the recent literature with reference to each of the traditional fields within Engineering Technology and Engineering. What exists is an overlap

in place of an interface. It has been estimated that there is currently an eighty-five percent overlap between these two types of disciplines. Delineation at present hinges upon the higher mathematical abstractions in Engineering and greater laboratory applications in Technology. As technologists secure professional registration, P.E., the overlap will become greater. In another plane of thought, the use of the computer will continue to erode the mathematical distinction.



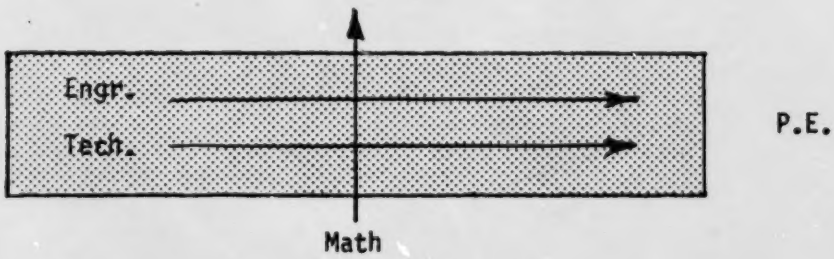
A serious consequence to this interface is our national concern with economic accountability. Can we justify the increased expenditure for shops and laboratories to support two separate programs that in reality have such a common denonimator? It is the author's belief that two separate programs can be justified if the facilities are established with joint usage of function for both forms of education and the faculty utilize these facilities within the philosophies of each particular discipline. To effectively accomplish this goal would call for close adherence to the construct provided on page 22 or the development of a different construct which delineates the differences. DAVID F. LINOWES, in his book, Strategies for Survival, provides a plan for

non-profit entities such as educational institutions to successfully perform their functions by use of Socio-Economic Management. These strategies are known in the world of business and can be translated, monitored, and evaluated in non-profit institutions. He states:

> What we desperately need are ways and means of improving social earnings (fulfilling human needs) along with traditional corporate earnings. Part of the solution lies with technology, the very phenomenon that has contributed to so many problems. (12)

In conclusion, then, we must look to human fulfillment as well as economics to justify any program of shop and laboratory utilization. Some have supported the concept that the problem would be more manageable if there were a dual track available in our current programs of Engineering Education.

ENGINEERING EDUCATION



There are, of course, many advantages to such a structure, management of people and material resources being the greatest. However, the problem of maintaining identity increases. Whatever the final structure becomes, it must reduce cost if this nation is to compete in world markets.

Q 4. What commonalities exist between these different forms of technological education?

A 4. The commonalities between these various forms of

technological education are found in the utilization of industrial hardware. It is the purpose to which this hardware is directed. The hypothetical construct described on page 26 is based upon the several steps in the scientific method. Each area of employment specializes in some basic function. The educated man recognizes that there is dignity in all labor and that an equality should exist between these different coordinated activities that translate theory into practice. The value has traditionally followed cost of preparing oneself for a specific occupation. Currently there has been greater development and more growth requirements on the operational side of the spectrum. This statement does not imply that extensive change has not also been required of the Engineer and the Scientist. The construct on page 17 shows that there are a number of areas of professional education covered in the upper division. This change is also easily seen in the entry wages earned by the graduate with the B. S. Degree.

Q 5. What is the current status of Engineering Technology?

A 5. At present it is in limbo. Industry has not yet subscribed fully to the terminology that has been created. Educational institutions have a real challenge in gaining acceptability for this concept. On the other hand, Industry is more than willing to hire the man who can meet the specific needs of the industry. Industry readily creates job titles for their specific needs and in all probability will never agree with the concepts of the educational institution.

Traditional majors in engineering cast a jaundiced eye upon this new upstart. Technology has filled the gap as Engineering has moved to the scientific end of the Engineering Spectrum. As requirements decrease for the pseudo-scientific engineer, major engineering

departments will once again enter into engineering activities now which are within the Technology spectrum.

Q 6. What significant trends are under way?

A 6. In the area of shop and laboratory instruction in technical education the most significant trend has been, is, and may continue to be, the removal of laboratory instruction for engineers in favor of more lecture. It is the author's considered opinion that this trend will be cut short, for Engineering can ill afford to cut itself off from the development of new knowledge.

Other trends include the earning of advanced degrees in all fields of endeavor, the need for more expertise in original research, need for larger class sizes based upon economic factors, need for replacement of bulky equipment with items designed specifically for instructional use, need for versatility in laboratories devised for multiple use, need for students to get a fix on research as a process, need for more people to experiment, and above all else, a need for evaluation of Technology as a total system of learning.

Q 7. What need does Engineering Technology fulfill?

A 7. There is, and will continue to be, a real need for theoretical engineers who will operate close to the science spectrum. However, there is a greater need for qualified people who can accomplish a given piece of work that contributes to a greater whole. Specialists are in demand and they do not need to have in hand, the more rigorous background of the Engineer. It is important to note that many technologists, in time, gravitate to the engineering level by taking additional work or individual study. There is no final relegation for the human spirit knows no bounds. Individual motivation

appears to be the key to further development.

The question that goes unanswered is, "Are we creating an engineering group of less ability, or are we only optimizing the concept of specialization a step further?" It is the author's belief that as advanced societies move forward there is always a need for more advanced specialization.

Q 8. What appears to be the major constraints or limitations of shop or laboratory requirements in Engineering Technology?

A 8. The major constraint is the provision of more appropriate instruction in terms of behavior change when equipment and maintenance costs are so high. Even the wealthy institutions not faced with the constraint of cost and time must deal with the instruction of technical material on the basis of available instructional time. Available time appears to be the major criterion for present judgments on utilization of laboratories.

Another constraint for all forms of technical education is keeping abreast of change. The industrial functions are not always clearly seen from the academic end of the spectrum. The true significance of things depends upon seeing the total relationships of the two.

It is, of course, impossible for the laboratory form of instruction to keep pace with industrial development in its many varied forms. An in depth analysis needs to be made to determine how educational laboratories should be structured and to determine the methods by which the educational process can be optimized, so that a guide might be developed for technical education. Industry also stands in need of guidelines for its many research facilities in light of the

many different functions performed.

Q 9. What are some possible courses of action open to Engineering Technology?

A 9. To obviate the need for extensive facilities educational institutions can implement internship programs, co-op programs, industrial visits, work study programs, and other on-the-job possibilities to supplement the educational institution's facilities. Some stress can be taken away from overused facilities by requiring laboratory reports and other written exercises. The computer, if available, can be used for simulated programs in lieu of laboratory experimentation. Pedagogical reports based upon the status of knowledge stored in our libraries can fill certain needs. This last approach aids the student in seeing how others have scoped their projects.

Future careers are frequently based upon experimental projects undertaken. Most educational courses do not offer an opportunity for analysis and an opportunity to synthesize the pieces into a consistent whole in terms of thought and action. <u>There is no other form of education that can provide the exact functions performed in laboratory education</u>. The need for personal engineering projects is valid and should not be drawn and quartered by economically conscious administrators. If constraints are placed upon laboratory utilization, opportunities for creativity are limited.

Institutions can be made effective only if we devise new approaches and establish systems of continuous evaluation.

Q 10. What is the educational process that shapes the development of shops and laboratories in technological education?

A 10. Research, development, and experimentation should help shape the educational environment. In the past, industrial surveys of need and families of occupational clusters have assisted some forms of technological education in the development of appropriate facilities. This approach to curriculum has a rather weak base in light of all the opportunities these forms of education offer.

Programs should have quality, scope, and depth. Programs should supply educated people for the mounting demands in the world of work. In doing this, economic and social dislocations should be kept to a minimum. GRANT VENN in Man, Education, and Work makes the following statement:

> To understand the problem more fully, we must look behind these symptoms and examine the new technology and the nature of the changes it has wrought in the relationship between man, his education, and his work. (13)

The most obvious means and manner of giving shape to our shops and laboratories is to determine the behavior changes we hope to elicit. Objectives and curricula are then established to provide these changes.

Q 11. What constitutes a meaningful shop or laboratory experience in technological education?

A 11. As stated above in answer to question 10, a meaningful laboratory experience is based upon securing a behavior change in the student that is appropriate to the objective of the lesson, course, or program of studies that would not have been obtained in regular formal class instruction. To be truly of value it must be useful to the student or must prepare him for future occupational tasks.

Q 12. What are some of the various roles the student plays in laboratory work?

A 12. The chief role of the student is that of being a learner. However, he is also a transmitter of knowledge, in that students learn from each other. Many times a fellow student can appreciate a problem by virtue of his own exposure to the problem, whereas an instructor may be removed from the problem by virtue of his age.

It is expected that the student will also develop a role with regard to his occupational plans. The functions of engineering can be viewed in terms of role. Some of the functions are as follows:

1. Research
2. Development
3. Design
4. Production - Construction
5. Operation - Maintenance
6. Sales - Application
7. Industrial Systems
8. Management

Q 13. What roles are typical of the instructor of technological laboratories?

A 13. First and foremost he should be an educator. He should also be a model worthy of emulation in his own area of specialization. The educator usually follows the role to which he has been exposed in his own educational development. The outcome may be either good or bad.

A sub-role of the educator is to transmit the known culture, i.e., the state of the art, technology, or science. An additional sub-role is that of improving upon the culture by creating an atmosphere of intellectual curiosity and research. The laboratory is a natural place to create lifelong behavior changes for the student. It is

the only place where the student can learn about the value of the laboratory as an indispensable tool.

Q 14. How does the Engineering Technology laboratory differ from other forms of technological laboratories?

A 14. Engineering Technology laboratories should be more comprehensive in terms of facilities as Engineering Technologists are responsible for a systematic approach to goal accomplishment. Engineering facilities provide a measure of reality by which the engineering student is exposed to the developing process of problem solving. The engineer needs laboratory experience capable of giving breadth, for his skills in analysis and synthesis need to be developed within a wide range of activities. Traditionally, engineering schools have sought to provide this experience within the specific areas of specialization, i.e., Aero, Civil, Chemical, Industrial, Electrical, and Mechanical Engineering.

Engineering laboratories are also similar to Technology laboratories in terms of purpose. F. MORRIS reports the following use of Engineering laboratories:

> The laboratory, then, is a place to work, to think, to explore, to experiment, and to exercise ingenuity and resourcefulness to make things perform in a desired manner. It is knowledge in action which, in turn, results in more knowledge.
>
> In engineering education, laboratory experiments are a fundamental part of the learning process. The knowledge of theory that is gained in lecture is understood better and retained longer when it is used in practical applications. If knowledge is not used, it is often devoid of meaning, is vague and transitory. Theory and practice are so closely related that they should be treated as parts of the same thing; therefore, if the students are to get the maximum benefit from a course, lecture and laboratory work should be more closely coordinated. (14)

A great deal of difference should exist in the equipment provided for engineering education and engineering technology education. Models and synthetic devices can serve the engineer admirably as the emphasis is upon understanding the principles rather than upon knowing specific pieces of gear. Engineering Technology demands a firsthand acquaintance with the specific types of equipment that the technologist must correlate into a conceptualized system. He also does not need to be intimately concerned with the specifics of equipment operation, but rather, he needs to know what can be accomplished on a specific piece of equipment, i.e., purpose, limitations, quality and quantity of work to be expected under various conditions. The technician is expected to be experienced in setting machines up to secure the desired results, i.e., speeds, feeds, surface finish, concentricity, tolerance, etc. Conceptually, the operator needs to know the art of making a specific machine perform in an optimal manner. In reality many operators are but an extension of the device or machine. Operators rely upon the specialist for much of the information required in achieving optimality. On the opposite end of the spectrum, the scientist needs to know only how a certain thing can be done to cludge together gear to test his ideas.

Before leaving this topic, attention should be directed to the faculty that will use the facilities and equipment associated with each of these various technological programs. In some cases a man can be totally conversant in all aspects of a machine, its use, and required physical skills. In general, this is not the case because of the complexity of the machine industry. It is a large

and diversified field that is growing rapidly so that it is no longer possible for one man to be specialized in all aspects. Faculty use of laboratory equipment must be based upon objective visibility for the specific program being taught. This must be translated into a specific program which elicits the desired behavior change in the student in keeping with the desired objectives.

Q 15. What other forms of experience can be substituted for laboratory instruction?

A 15. This question is related to the answer given to question 9, page 35. All forms of experience at the actual job site provide a form of substitute experience. In addition, the concepts used in the presentation of audio-visual material are valid. Models, mock-ups, charts, graphs, slides and film can be utilized.

The more pertinent question is how effective are each of these various forms as they can be found on a scale of effectiveness? Obviously, the specific conditions surrounding the experience determine the possibilities.

As indicated, Industry represents the real world and it is there that we can find all the facilities and equipment that provide the vehicle for the proposed laboratory work. No two companies are identical and each is organized to serve some specific function. While it is true that they employ similar methods, they are not necessarily equal in terms of opportunities for learning.

Man has taken only the first step with reference to providing optimal educational experience. The author doubts that a laboratory exists anywhere that could not be improved upon if ample time and money were made available.

Q 16. What options exist for maximum laboratory utilization?

A 16. Maximum laboratory utilization can be accomplished in many different ways. It should not be defined in terms of students in the facility during available hours.

The quality of maximum utilization should be based upon optimal behavior changes. WILLIAM E. WICKENDEN states:

> Four things an engineer must have: a mastery of applied science, an instinct for economy of effort and of cost, the power to visualize ideas by imagination, and the power to express ideas clearly in speech, or writing, or drawings to other men. (15)

Laboratory experience must assist in securing these types of behavior change. The quality of maximum utilization should be based upon optimal behavior changes. Such a criterion for judging effectiveness would call for a complete restructuring of facilities. At present, laboratory facilities aim at simulation of industry. Though this will remain as a key element in all technological instruction it should be relegated to a position below that of meeting educational objectives. Optimal behavior change must be secured.

Attempting to replicate industry in even a modified form is an expensive process which can never be achieved because of costs and the rapid rate of change which takes place in all spheres of industrial activity. However, if the several various forms of technological education were to utilize the same facilities, the cost of laboratories could be markedly reduced. This is true only up to the point of maximum student use. At this point additional facilities would need to be secured and greater specialization allowed to occur.

What is of concern here is the need for a new conceptual process which could structure comprehensive laboratories that meet a

variety of needs and serve to elicit specific behavior changes. Such a program would be concerned with blocks of learning experience rather than just blocks of time. Learning experiences directed to specific ends should be the rule. Today learning is an accidental process which, by necessity, must be structured by the learner. Too often educators are satisfied if they know that some learning experience is taking place. The future will demand that we know how to elicit the exact learning behavior required. Nations rise and fall based upon their ability to develop the educational expertise needed in an optimum manner.

Q 17. How may laboratory experiences be evaluated against the more traditional rigid criteria for laboratory requirements?

A 17. MARVIN J. CETRON and others in the text, Technical Resource Management Quantitative Methods point out a vital fact concerning evaluation:

> Taking this discussion back to Technology, it was stated earlier that the assessment of Technology depends on who does the assessing, why the assessment was undertaken, and on the nature of Technology itself. (16)

Obviously, what is needed is a criterion that negates Cetron's statement. It is the author's opinion that evaluation should be based upon predictors which indicate that the behavior change has taken place in the student. The student's achievements are frequently tested by formal test questions or by giving performance tests.

The purpose of shops and laboratories in the field of education is to assist the student in the development of knowledge, understanding, judgment, and skill. It involves both thought and action processes. The general method is best described as the use

of the scientific method.

> It is believed that one major task of all research undertaken is to direct attention and observation to new findings which appear to be the present boundaries of completeness. New direction begins with the new development of intellectual speculation based upon intuitive insight. The search is not for ideas as they never seem to modify practice. The real search is instead for new theories or explanations which will dictate new operational procedures. The researcher believes that the new era of education will focus upon teaching people how to think, not what to think. (17)

How refreshing it would be to have a new criterion of actual educational development. How could we evaluate the process? If adequate inputs or provisions are made for the learning process, then specific outputs will be produced. These outputs have been described in this paper in terms of behavior change. A general classification of types of behavior are as follows:

> The following hierarchial order or classification explains the researcher's ideas relative to behavior.
>
> 1. Abilities--inherited capacities capable of performance.
>
> 2. Interests--the phenomena of mind which attracts or repels the individual during the process of independent investigation.
>
> 3. Attitudes--indicate the disposition the individual has made between his potential energy and his contact with specific factors of reality. It is indicative of inconclusive evidence being gathered or choice without understanding.
>
> 4. Knowledge--cognition of basic truth by utilization of the direct intrusion into the mind of something foreign to it, yet related to the sum of ideas whose values have been established and stored in the memory of the individual.
>
> 5. Appreciation--is the accurate recognition of truth that comes through full realization of knowledge and understanding as contrasted with attitudes based on inconclusive information.
>
> 6. Habits--are repetitive acts which are tailored to

the physical and mental patterns developed through adaption to the forces operating in the environment. It is one basis for action.

7. Skill--is contingent upon the development of precise thought and/or action with respect to time, and it is only fully developed when thought and action processes are closely interrelated. It is also defined as the ability to repeat the same action the same way more than 50 percent of the time. (18)

Obviously an experience for the student may terminate at any point upon the scale. In general, he may follow the sequential order to any particular point on the scale. It is difficult to conceive of anyone learning anything without utilizing his capacity and interest to initiate the process. In a similar vein, it is difficult to conceive of anyone having developed habits and skills without understanding. The point to be made is that thought and action processes are related. Psychologists have found that action processes tend to reinforce knowledge obtained.

NEWMAN A. HALL, Ed., Britannica Review of Developments in Engineering Education, reaffirms the previous statement made about the value of laboratory instruction:

> The laboratory provides the essential contact in engineering design and development with reality. As such, its role in the education of the engineer is intrinsic and fundamental. The engineer who presumes to reject the experimental test inevitably turns his back on reliability and workability. Such an attitude, which could be established by an inadequate education can, in the long run, serve to discredit engineering accomplishment. (19)

JOHN D. KEMPER in his book, The Engineer and His Profession, further elaborates upon the advantages of laboratory work. In his discussion of the Preliminary Goals Report by the ASEE he states:

> The report strongly urged laboratory experiences because of the "feeling" for the actual physical situation laboratories can provide; and because, by permitting evaluation of

> the performance of designs, such experiences may lead to the discovery of results not anticipated by theory. (20)

Plainly, any program of evaluation brings to bear the structure, function, and methods utilized. Inputs vs. outputs and the achieved outcome of the program are critical factors. Achieved outcomes must be equated to exposure time for required behavior change and expenditures for facilities, equipment, materials, records, and faculty. In addition evaluation should account for total success or failure, relevance of curriculum, faculty effectiveness, facility and equipment utilization, student morale and acceptance, and the fulfillment of societal need.

If progress can be equated in terms of behavior changes then progress toward all higher goals will occur.

Q 18. What controls appear to be necessary to guide the development of Engineering Technology laboratories?

A 18. Perhaps the major control for the development of Engineering Technology laboratories is the same as the need for the development of Engineering Technology skills. HUGH FOLK in his treatise, The Shortage of Scientists and Engineers, states the following:

> Engineering demand is demand for certain technical skills rather than demand for certain technical people. These skills are usually highly specialized and are quite unstandardized. ---Engineers are employed because of what they can do or what they can learn. (21)

It is not difficult to translate this same idea to all the various fields of technological education, for each requires a similar but different set of technical skills. The first control, then, is need for the product being turned out.

A second control of major importance is the division of time alotted for each behavior change to be elicited. The effectiveness of laboratory instruction vs. traditional theory by lecture must be recognized. A third control is funding. This control is not valid if appropriate experience is not taking place because of inadequate funding. Costs are valid only when adequate funding is provided. In the American Management Association Report, Optimum Use of Engineering Talent, the following is stated:

> The problem of selecting facilities therefore resolves itself into achieving a balance between the desire of the engineering department for maximum facilities and the desire of the profit-center manager for zero investment in engineering assets. Adequate procedures and controls over the selection and acquisition of facilities are necessary to satisfy both desires. (22)

Engineering Technology personnel make even greater use of the equipment than the Engineering group. Technology greatly desires a wide coverage of machine types plus machines with greater specialization. The control that appears to be most appropriate in the development of Engineering Technology laboratories could be called educational justification. Just as industry uses economic justification for the purchase of new equipment, the faculty should be able to show the extent to which a new piece of gear will be used for instruction and the specific behavior changes expected based upon student use.

Q 19. What effect do employment opportunities have with respect to shop and laboratory experience in Engineering Technology?

A 19. Employment opportunities with respect to shop and laboratory experience are first related to the size of the company and the number of technological people employed. The National Science

Foundation in its report, Science and Engineering in American History, provides the following data in 1954:

Company Size by Total Employment	Number of Engineers	Percentage
8 - 99	37,600	9.2
100 - 499	50,500	12.4
500 - 999	21,400	5.2
1,000 - 4,999	66,300	16.2
5,000 or more	232,900	57.0
Total	408,700	100 %

(23)

Obviously, employment opportunities are greater in companies employing 5,000 or more employees. One could also assume that these larger companies support more extensive shops and laboratories. One might also speculate that larger companies provide a greater division of labor and thus require greater specialization. If the above rationale is correct, then educational shops and laboratories have a need for more extensive equipment which would aid in specialization.

LEE DANIELSON in his book, Characteristics of Engineers and Scientists, makes the following statement:

> Engineering schools don't provide the background that is necessary for a man to do a job in industry. An engineer must know how to use the facilities around him. He must understand the shop and the processes used to get things done. For instance, a university graduate may start using a lot of formulas and complicated calculations. We don't have to go through all that procedure because we have experience. He may take all day to calculate the motor requirements for a machine but we know them from experience. A university should give a student work experience in addition to theoretical training. (24)

GEORGE C. BEAKLEY AND H. W. LEACH in their text, Careers in Engineering, point out another important fact about technological employment:

> It should be realized, however, that the completion of a college course is not the end of study for an engineer. The pace of discovery is so rapid today that, even with constant study, the engineer barely can keep abreast of technological improvements. If the engineering graduate should resolve not to continue his technical study, he would be far behind in technology within five years and probably would be completely out of step in ten years. (25)

No one knows for sure what the future holds; however, one can state with accuracy that the future will continue to require ever greater needs for technological capability, i.e., the application of math and science to the optimum conversion of natural resources to benefit man. Just as assuredly one can state that employment opportunities with respect to shop and laboratory work will continue to increase and become an even greater aspect of technological education. RALPH J. SMITH in his book, Engineering As A Career, emphasizes the value of the laboratory:

> Laboratories provide training which can not be gained otherwise. In addition to spoken or written words which are abstract symbols of real things, experimental work provides information gained through the senses of sight, smell, touch, taste, and hearing.---The purpose of laboratory work is not just to illustrate the theory of the text and lecture. Rather it should serve to emphasize the distinction between theory and practice. It should develop skill in the experimental method which forms the basis for the development of all science. It should provide practice in observing, recording, and reducing data and drawing conclusions therefrom. It should lead to an appreciation of the limits of precision of scientific measurement. It should in the case of engineering, provide an understanding of the practical problems of starting, controlling, and operating engineering equipment. (26)

Q 20. How can the analysis and determination made in this study serve Engineering Technology?

A 20. This study serves primarily in four areas. First, it directs the reader to a wide array of informative facts. Second, it indicates current trends and possibilities for the future. Third, it

emphasizes the most essential findings. Fourth, it provides the author with an opportunity to set forth his own insights as a conclusion to this study. In brief, the essential concepts touched upon are as follows:

(1) Emphasizes shop and laboratory activities as an indispensable part of all technological education.

(2) Provides a profile of characteristics related to shop and laboratory work.

(3) Shows that shop and laboratory work are an indispensable tool to be developed by technological personnel.

(4) Emphasizes that more time should be devoted to experimental work in shops and laboratories.

(5) Points up need for in-depth study of methods to develop competencies in shop and laboratory.

(6) Touches upon need for a totally integrated system of technological education.

(7) Emphasizes the revolutionary advance in science and technology.

(8) Provides some historical background to show why technological education is dynamic and that further change will occur.

(9) Gives an overview of technical scientific education in the public schools.

(10) Identifies types of shops and laboratories; their function, basic organizational concept, essential method of problem solving, and types of equipment.

(11) Provides construct of technical scientific employment, overlapping operations and joint responsibilities.

(12) Places emphasis upon scientific method as the key to applied science.

(13) Provides a look into the future in terms of new types of laboratories that will eventually emerge.

(14) Points out the fallacy of the current trend to eliminate laboratory work in Engineering Education.

(15) Shows indication of some limiting factors.

(16) Cites need for new approaches.

(17) Places emphasis upon behavior change as the key to development of laboratory facilities.

(18) Lists functional roles of technological work the student experiences.

(19) Indicates that the instructor's role is to create behavior changes.

(20) Identifies Engineering Technology laboratories by a systematic approach to goal accomplishment.

(21) Provides a list of alternate activities currently used in lieu of laboratory experience.

(22) Indicates program development should be based on blocks of learning experience, rather than upon blocks of time.

(23) Places emphasis upon how to think, not what to think, as a basis for educational development.

(24) Indicates classical types of behavior changes.

(25) Elaborates upon problems of evaluation.

(26) Introduces some control factors.

(27) Points out employment opportunities.

CONCLUSIONS

The national welfare of this nation can be assured only if appropriate technological competencies are developed within our society in sufficient numbers to assure a posture of world leadership in the field of applied science. The appropriate competencies can be obtained within the structure of the Federal Government, Industry, and our Educational Institutions.

Public educational institutions can improve their efficiency if they begin to utilize some of the techniques employed by the federal government in its many different institutions. Traditionally, the government develops competencies in a short period of time. Only large industry can expend funds to achieve the same ends as the federal government. Industry must produce in an optimum manner. If this is not done in a capitalistic system, companies and corporations cease to exist. Some few companies are willing to share their stockholder's profits by setting up programs for students who will not become members of the organization. Some modest programs are offered to attract talent that is about to be topped out. Usually these programs are in lieu of expensive recruitment, especially if the company is one which must have a continuing supply of expertise and knowledge to remain competitive. Too frequently programs of training in industry deteriorate to programs of inexpensive labor supply with the student performing tasks leading to corporate ends rather than optimal educational development. For the foreseeable future most of the technological expertise will have to be developed within our educational institutions.

Educational institutions are frequently restricted by virtue of the funding process. The question that must be answered is, "What should the balance be between developing an optimal educational environment and keeping expenditures at a minimum?" The author of this paper feels that a balance can be made based only upon the criterion of achieving appropriate behavior changes in an optimum manner. Behavior changes can be tested and performance tests used as possible checks.

Exposure time required to develop the required behavior can be measured in terms of time and money supplied to secure facilities, equipment, materials, systems of record keeping, and adequate personnel. Industrial methods of costing can be applied to obtain exact educational cost for specific functions and facilities. Only when we can equate educational costs against learning outcomes will it be possible to optimize our system of education.

Laboratories must be evaluated upon their contribution to securing specific behavior changes. As this paper has indicated, some behavior changes can be learned only in the laboratory. Some behavior changes can be achieved within a variety of settings and in combination with other forms of instruction. What is sorely needed is an in-depth investigation of what curricula and methods achieve the desired behavior changes in the most optimum manner.

There are many forms of technological education offered in the United States. Each develops and operates its own program and not enough attention is directed to providing continuity for the student. Establishing such a system would conserve time and

money and at the same time look to the social issues of job satisfaction.

Within academic institutions laboratory alternatives are dispersed upon a spectrum with maximum laboratory utilization at one end, and no laboratory utilization at the other end. It will always be true that theory can be given at minimal cost whereas laboratory utilization is more costly. Can we afford arbitrary decisions? Can we afford not to subject various programs, plans, and concepts to the research method? Now is the time to determine optimal ways of securing required behavior changes.

The best way to secure interest in this field of endeavor appears to center around visibility of purpose. For this reason, this study will be concluded by a listing of advantages of laboratory instruction. The advantages in some cases appear to have similar elements; perhaps the various contributors had a similar idea in mind. The purposes and advantages of laboratory instruction follow in an unranked list.

Shops and Laboratories:

1. Are the scenes of new discoveries.
2. Stimulate further developments in technology.
3. Improve operations of theoretical engineers.
4. Serve to develop an instinct for economy.
5. Provide a measure of reality.
6. Provide opportunity to make full utilization of the scientific method.
7. Relate theory to practice.

8. Provide specialized experiences.
9. Frequently suggest new studies.
10. Are in themselves a problem solving process.
11. Provide opportunities for education in human relations.
12. Have theraputic value in that they provide for a release of tension.
13. Allow for the testing of theories.
14. Provide a measure of career guidance.
15. Relate thought and action processes.
16. Are dynamic methods of learning.
17. Can assist in developing specialization.
18. Develop the visualization process.
19. Are, as an educational process, frequently easier than theoretical analyses.
20. With extensive use of models, eliminate worry about all considerations of factors taken into account.
21. Provide pre-employment experiences.
22. Provide for the development of new interest.
23. Serve as aids to instruction.
24. Develop practicing engineers.
25. Utilize mental capabilities of absorption, retention, reasoning, and creativity.
26. Provide specialized experiences.
27. Can be used in the preparation of training aids.
28. Provide for dynamic processes of development from a general education base.

29. Can provide certain types of behavior change more readily.
30. Can be designed to instill technological competency.
31. Are used in teaching basic instrumentation.
32. Teach the technique of analysis of experimental data.
33. Provide opportunities for practice in technical communication.
34. Develop attitudes of research.
35. Teach the organization of texts.
36. Provide for both vicarious and directed educational processes, by moving from experience to the learning and moving from the learning to experience.
37. Meet the needs and interests of students.
38. Are valuable in the introduction of concepts.
39. Provide the opportunity to work with real equipment.
40. Provide for the development of models to subsume information.
41. Provide some opportunities for supervision and management through group projects.
42. Teach people to experiment.
43. Provide continual reinforcement in the learning process.
44. Help the student make future value judgments.
45. Provide an essential tool for intelligent research.
46. Provide opportunities to learn basic skills.
47. Provide opportunities to establish control procedures.
48. Are valuable in the process of discovery learning.
49. Add interest and challenge for youth.

50. Provide explanations of the less obvious aspects of technological education.
51. Allow for integration of concepts.
52. Simulate systems by devices to provide the basic action of systems.
53. Provide the individualized experiences.
54. Are tools for expression in drawing.
55. Serve to supplement and strengthen subject matter.
56. Give purpose to the teaching of theory.
57. Provide practice in writing engineering reports.
58. Awaken scientific curiosity.
59. Can serve as a basis for the cultivation of good work habits.
60. Develop techniques in the use of equipment.
61. Teach the importance of scientific procedure in scientific investigation.
62. Provide for socialized experiences.
63. Provide experience in the evaluation of experiental data.
64. Provide experience in real situations.
65. Assist in the recognition and formulation of problems.
66. Lead to the introduction of many of the materials used in the field.
67. Develop consciousness of values and costs.
68. Develop appreciation for the process of innovation.
69. Put emphasis upon the human factors in engineering.
70. Develop a critical point of view.

71. Offer ample opportunities for self-development and improvement.
72. Emphasize the concept of reliability and workability.
73. Help pace rapidly expanding technology.
74. Move pedagogical math back to an experimental base.
75. Develop new knowledge through experimentation.
76. Allow for computer facilities to simulate or extend potentially useful projects in problem solving.
77. Develop skill in construction of laboratory apparatus.
78. Give significance to courses by providing for the development of teaching theories.
79. Give students an approach to problems similar to those experienced in engineering practice.
80. Develop self confidence.
81. Peinforce the scientific and engineering principles given in lecture courses.
82. Aid in the development of judgment through valuable experimental investigations.
83. Provide introduction to related techniques and supplement classroom instruction.
84. Can develop proficiency in manual skills.
85. Develop a framework of mind and the techniques which should enable the graduate to play his proper role in industry.
86. Develop habits of careful investigation.

87. Assist students in translating various academic program requirements to the students' conceived objective of use and application.
88. Provide first hand experience as opposed to information obtained from printed page.
89. Provide training that cannot be obtained otherwise.
90. Serve to emphasize the distinction between theory and practice.
91. Provide practice in observing, recording, reducing data, and drawing conclusions.
92. Allow for the development of teamwork.
93. Develop inventiveness.
94. Put emphasis upon the application of knowledge.
95. Help provide realistic expectations of work in Industry.
96. Stimulate students to develop to their maximum.
97. Allow for problem solving of a practical nature.
98. Open the door to adventure.
99. Provide a moment of reality.
100. Frequently allow for the discovery of results not anticipated by theory.

It seems appropriate to conclude this list of advantages though there are many more that could be listed. At the same time, full recognition is given to the similarity of some items. The laboratory is not limited in scope and is modern in conception. To be properly used it must be dynamic and constantly changing.

The educator should ask such questions as:

1. What are you going to do?
2. Why are you going to do it?
3. How are you going to do it?
4. What will it replace?
5. What ideas will it teach?
6. Where will it fit in?

WHINNEY states:

> The use of the laboratory in education is for the purpose of giving students active and direct experience by letting them do the things that they have read about--- The laboratory then is a place to work, to think, to explore, to experience, and to exercise ingenuity and resourcefulness to make things perform in a desired manner. It is knowledge in action that, in turn, results in more knowledge. (27)

Someone once said that a practitioner of applied science, who does not have an adequate background in shop and laboratory work, is akin to a surgeon without practice. It is hoped that each reader of this article will reappraise the values of shop and laboratory instruction and personally provide more opportunities for his students. As a professional group we must insist upon optimal educational experiences.

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